Nano-SMA fiber Composites Development and Applications

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- Collaborator: Tamagawa, H., Gifu U, Japan (polymer synthesis)

- Technical Effort
  - Smart Structures for Extreme Environmental Conditions
  - Nano Shape Memory Elements
  - Robust, high performance / SMA fiber 1μm or lesser (2007)
  - Affinity, light weight, low cost, productivity / SMP fiber 100nm (2007)

- Science
  - Nano-effects in Phase transformation in metal and in polymer

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14. ABSTRACT

We design a set of self-strengthening AMCs with shape memory nanofibers with the aim of inducing compressive stress at different use temperatures; (i) high temperature for leading edge structure panels or those near engine and (ii) low temperatures for composite face sheets of AF cryogenic tanks. To this end, two types of SM nanofibers will be used, shape memory alloy (SMA) and shape memory polymer (SMP). SMA exhibit phase change at transformation temperatures (Ms, Mf, As, Af) while SMP exhibits a similar phase change at Tg. This project is aimed at creating a set of new deigns of autonomic multi-functional composites (AMCs) by interacting with researchers in different disciplines, Polymer Chemistry, Materials Science and Engineering, and Mechanical Engineering at the University of Washington (UW) and Hokkaido University (HU). The UW-HU team proposes to design self-strengthening AMCs for use in the composite structures in high and low temperature environments, particularly the face sheet composites of a AF reusable fuel tank. HU team is helped with additional sub-members, Dr. Tamagawa of Gifu University, and Dr. Yamamoto, Tohoku University, where Dr Tamagawa is expert in polymers, thus in charge of design and process of shape memory polymers and Dr Yamamoto is in Metallurgy, thus in charge of nano-shape memory alloy powders which are key starting materials for processing of nano SMA fibers. The key active and sensing material in designing the proposed AMCs is shape memory (SM) nanofibers where SM can be shape memory alloy (SMA) or shape memory polymer (SMP). SMA and SMP nano-fiber will be used for self-strengthening AMCs in high temperature (temperature change), or in low temperature. The key concept in designing self-strengthening AMCs is to induce compressive stress in the matrix material through a shape (or length) change in SM nanofibers upon temperature change. This compressive stress in the matrix is expected to suppress any cracking in the matrix. Use of ferromagnetic SMA FePd nano-fibers is expected to provide additional functionality to the self-strengthening AMC, i.e. (i) self-diagnosis if the composite is inspected by magnecto-optic-image scanner and (ii) stealth under radar detection

15. SUBJECT TERMS

Aircraft Structures, Smart Structures

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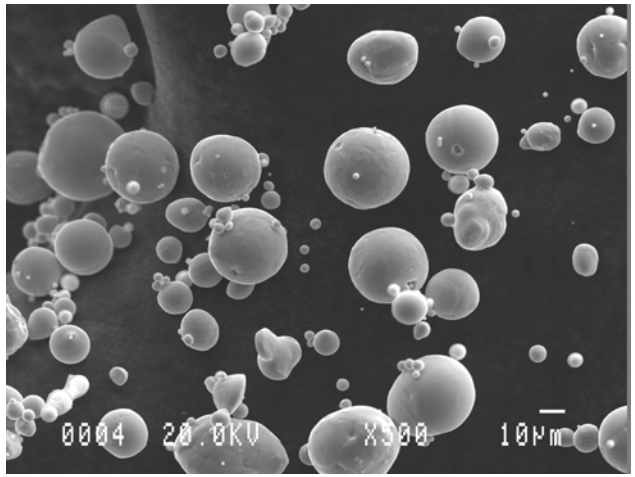
Nano-SMA fiber Composites Development and Applications
Scientific Approach & Accomplishment

Scientific Approach

- Down-sizing bulk SMA by gas atomization and electro-dissolving
- Synthesis approach for nano size SMP by electrospinning

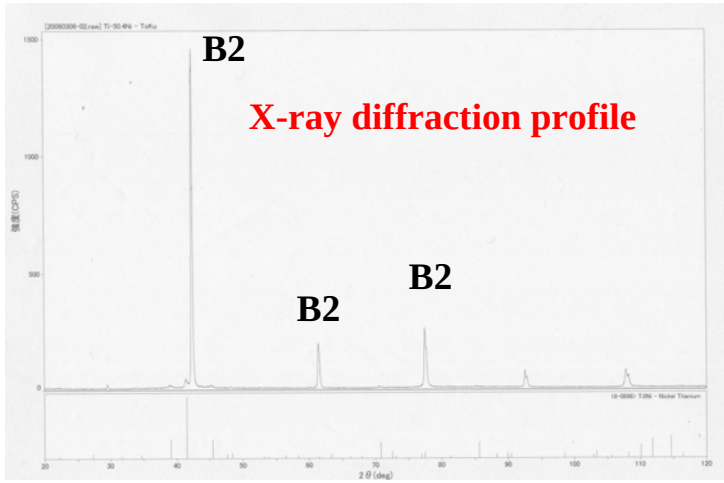
Accomplishment

1. SMA particles produced by gas atomization (HU)



Nickel-Titanium SMA powders

•the finest particles ever



angle

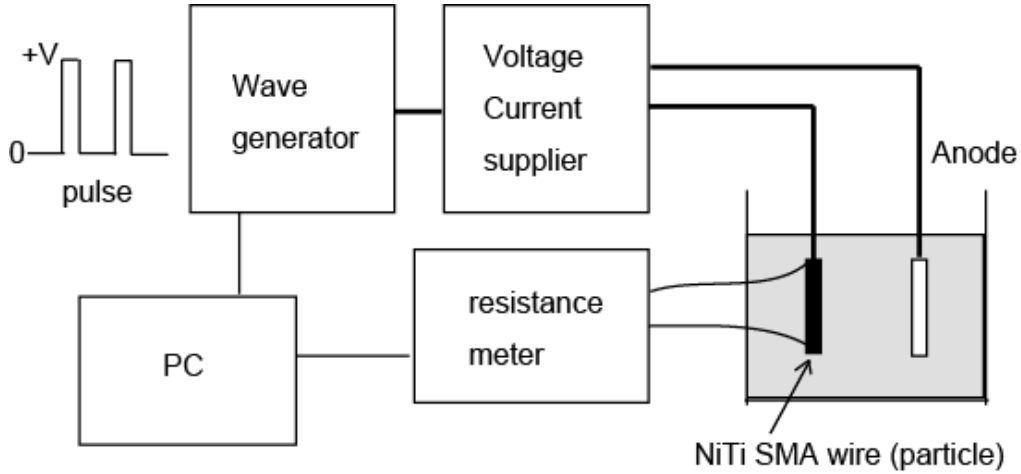
•impurity free
•homogeneous B2 phase

Accomplishment

2. SMA fiber produced by electro-dissolving (HU)

2

Nickel-Titanium SMA fiber 15μm dia.



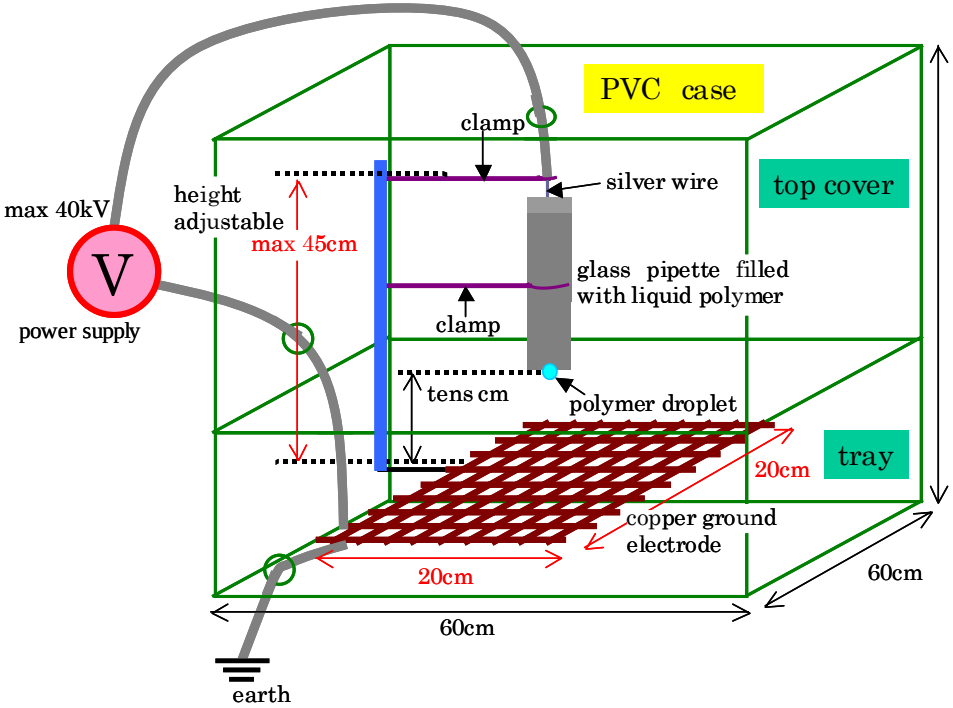
Electro dissolving with pulse current.

- Nickel titanium SMA with the smallest diameter ever,
- diameters: 15μm (Sep2006), 10μm (Oct), 3μm(Nov)
- Bamboo-structured fiber (Crystal grain size 8μm)

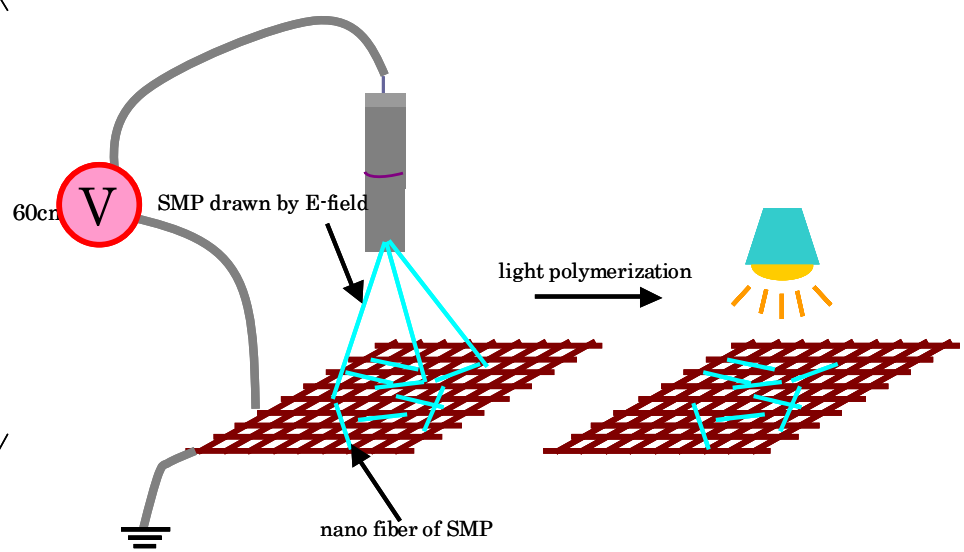
- Present purpose (HU)
  - SMA less than 100nm dia. affordable for tensile deformation
  - SMA reinforced FRP with low CTE

3. Synthesis approach for nano size SMP by electrospinning

- The synthesis machine has been built (Gifu-U)



Electrospinning machine



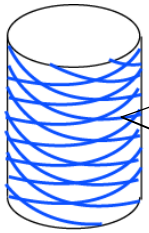
Method of polymerization

- the test run started Nov.29, 2006 (Gifu-U)

The outline of the project

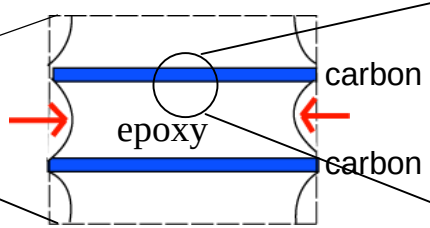
problem

FRP cryo-tank



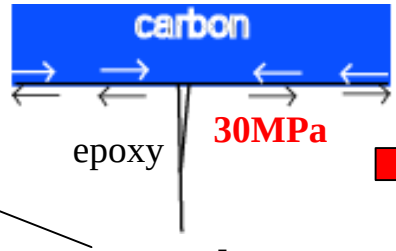
Filament Winding cylinder

CTE effect at low temp



$\Delta\alpha=5\times10^{-5}/K$
$\Delta T=300K$
$E=2GPa$
$E\Delta\alpha\Delta T=$**30MPa**

Internal stress state

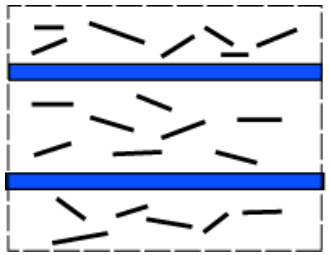


crack

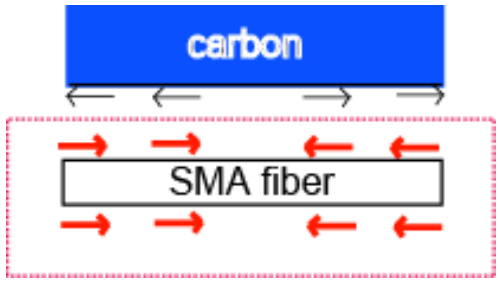
LH2 Leakage Accident

our strategy

SMA short fiber in matrix



internal stress cancelled out



Int stress reduction plus Fiber Strengthening effect

state-of-the-art technology